EG&G Idaho, Inc.

FORM EGG-2631#

(Rev. 01-92)

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ENGINEERING DESIGN FILE

Project/Task Borehole deviation survey

Subtask

EDF Page 1 of 13

TITLE: Gyroscopic directional survey of Central Facilities Area ground water wells, part II

SUMMARY

The summary briefly defines the problem or activity to be addressed in the EDF, gives a summary of the activities performed in addressing the problem and states the conclusions, recommendations, or results arrived at from this task.

A gyroscopic directional survey was conducted on ground water wells in the vicinity of the Central Facilities Area (CFA) Landfills II and III to measure borehole deviation from vertical because there was a question as to whether wells south of the landfills were truly downgradient. The survey was conducted by Strata Data Inc. of Casper WY. The rationale for conducting the study was that apparent anomalies appeared in water table maps when data from all wells were contoured. A closer look at the data, however, revealed that most wells drilled with the forward rotary method had apparent water levels that were lower than wells drilled using the cable tool or down hole hammer. Because there was not any obvious explanation for this anomaly, a hypothesis was formulated that the air rotary method produced less plumb and true wells than either cable tool or down hole hammer, and thus longer holes to reach an equivalent horizon, such as the water table. Borehole deviations ranged from 0° to 16° with wells drilled using the forward rotary technique tending to deviate more than either cable tool wells or wells drilled with the down hole hammer technique. Borehole deviation corrections at the water table for the May, 1993 water table data ranged from 0 ft to 6.32 ft. These corrections eliminated most of the anomalies observed in the water table.

Because of the large borehole deviations encountered in some of the wells drilled with the forward rotary technique, Strata Data Inc. had to use two different deviation tools. A low angle tool, which can measure borehole deviations up to 12°, and a high angle tool, capable of measuring borehole deviations up to 35°. According to Bruce McDonald, president of Strata Data Inc., the expected accuracy is $\pm 0.125°$ for the low angle tool, and $\pm 0.25°$ for the high angle tool. The accuracy of the gyroscopic survey is $\pm 1.25°$, or ± 0.11 ft for the low angle tool, and $\pm 2.5°$, or ± 0.42 ft for the high angle tool.

Because of the accuracy limitations (± 0.42 ft) it may not be appropriate to use wells surveyed with the high angle tool in contouring local area water table maps. On an even smaller scale, such as at the landfills, ground water flow will have to be inferred using surrounding wells having water table elevation differences greater than 0.22 ft.

Three point problems calculated using surrounding wells indicate that the gradient in the vicinity of the CFA Landfills II and III is to the south or south-southwest, and that wells LF3-8, LF3-9, LF3-10, LF2-8, LF2-9, and LF2-12 are on the downgradient side of the landfills.

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INTRODUCTION

A gyroscopic directional survey was conducted on ground water wells in the vicinity of the Central Facilities Area (CFA) Landfills II and III to measure borehole deviation from vertical because there was a question as to whether monitoring wells south of the landfills were truly downgradient. The survey was conducted by Strata Data Inc. of Casper WY. The rationale for conducting the study was that apparent anomalies appeared in water table maps when data from all wells were contoured. A closer look at the data, however, revealed that most wells drilled with the forward rotary method had apparent water levels that were lower than wells drilled using the cable tool or down hole hammer techniques. Because there was not any obvious explanation for this anomaly, a hypothesis was formulated that the air rotary method produced less plumb and true wells than either cable tool or down hole hammer, and thus longer holes to reach an equivalent horizon, such as the water table. Wylie (1993) found that borehole deviations ranged from 0° to 16° with wells drilled using the forward rotary technique tending to deviate more than either cable tool wells or wells drilled with the down hole hammer technique. Borehole deviation corrections at the water table for the May, 1993 water table data ranged from 0 ft to 6.32 ft. These corrections eliminated most of the anomalies observed in the water table.

In order to carefully evaluate positioning of the existing monitoring wells, the accuracy of each water level measurement must be determined. Only the most accurate wells will be used to construct water table maps, from which gradient in the vicinity of the landfills will be interpreted.

ANALYSIS

Wylie (1993) corrected water level measurements using the true depth for the nearest data points above and below the water table and fitting them into an equation using linear regression. This technique allows calculation of the true depth any where between these points. The corrected data was then used to calculate water table elevation. However gyroscopic survey tools have limited accuracy which must be considered when interpreting the data. Because of the high borehole deviations encountered in some of the wells drilled with the forward rotary technique, Strata Data Inc. had to use two different deviation tools. A low angle tool, which can measure borehole deviations up to 12°, and a high angle tool, capable of measuring borehole deviations up to 35°. According to Bruce McDonald, president of Strata Data Inc., the expected accuracy is ±0.125° for the low angle tool, and ±0.25° for the high angle tool. Strata Data Inc. collected deviation measurements every 50 ft, in general, so calculations from 8 measurements are incorporated before reaching the two true depth measurements reported on either side of the water table. Thus, 10 borehole deviation measurements are involved in calculating a corrected water level elevation.

The accuracy of the water table elevations can then be calculated; 10 borehole deviation measurements X 0.125 degrees = ±1.25°, or ±0.11 ft for the low angle tool, and ±2.5°, or ±0.42 ft for the high angle tool. Table 1 contains the surveyed wells, maximum deviation, and inferred accuracy. Although ±0.42 ft accuracy for the wells surveyed with the high angle tool may seem excessive, the water table elevation calculated in these wells was off by

Well Name	Drilling Method	Deviation (degrees)	Accuracy (ft)
LF2-08	rotary	9.0	±0.11
LF2-09	rotary	12.0	±0.42
LF2-10	rotary	10.0	±0.11
LF2-11	rotary	2.0	±0.11
LF2-12	hammer	2.0	±0.11
LF3-08	rotary	14.0	±0.42
LF3-09	hammer	2.5	±0.11
LF3-10	hammer	1.0	±0.11
LF3-11	hammer	1.0	±0.11
USGS-020	cable tool	2.0	±0.11
USGS-034	cable tool	2.0	±0.11
USGS-035	cable tool	3.0	±0.11
USGS-036	cable tool	1.0	±0.11
USGS-037	cable tool	0.0	±0.01
USGS-038	cable tool	1.0	±0.11
USGS-039	cable tool	2.0	±0.11
USGS-057	cable tool	1.0	±0.11
USGS-067	cable tool	2.0	±0.11
USGS-077	cable tool	0.5	±0.11
USGS-082	cable tool	2.0	±0.11
USGS-111	rotary	16.0	±0.42
USGS-112	rotary	11.0	±0.11
USGS-113	rotary	15.0	±0.42
USGS-114	rotary	12.0	±0.42
USGS-115	rotary	10.5	±0.11
USGS-116	rotary	5.0	±0.11

several feet before conducting the gyroscopic survey (Wylie, 1993). By way of comparison Atwood and Lamb (1987) reported a gyroscopic survey accuracy of ±0.30 ft at a site in the San Joaquin Valley of California where the depth to water was about 400 ft.

Figures 1 to 3 show water table maps for the landfills area in May 1993 without any corrections, with corrections, and without water table data from wells surveyed with the high angle tool respectively. Figure 1, plotted without making any corrections, contains numerous apparent closed lows which are typically indicative of areas of ground water discharge. However, these wells were not pumped prior to collecting the water level measurements. Based on this map ground water flow in the vicinity of Landfill III would be toward LF3-08, and flow in the vicinity of Landfill II would be to the east-southeast. Appendix A contains the water table data used to construct these maps.

Figure 2, plotted after making the borehole deviation corrections does not contain any closed lows when contoured on a two foot contour interval, however there are still some unusual perturbations. Note the loop in the 4456 ft contour line. The line loops up and around USGS-111 because the calculated elevation of this well is lower than the neighboring wells such as USGS-38 and USGS-77. Other inconsistences are visible on this map, for instance, LF3-08 is apparently higher than its neighbors LF3-10 and LF3-09, and LF2-09 is higher than its neighbors LF2-12 and LF2-08. The deviation survey on USGS-111, LF3-08, and LF2-09 was conducted using the high angle tool, because of excessive well-bore deviation. The accuracy limitations (±0.42 ft with the high angle tool) could explain these anomalies. Based on this map flow at Landfill III would be radially out from LF3-08, and flow in the vicinity of Landfill II would be radially out from LF2-09.

Because of the accuracy limitations (±0.42 ft) it may not be appropriate to use water level data from these wells surveyed with the high angle tool in contouring local area water table maps. Figure 3 shows the May 1993 water table map produced without the wells surveyed with the high angle tool. The loop in the 4456 ft contour line is eliminated, however, the water table is at the same elevation in all of the wells at landfills II and III, given the accuracy limits of the water level measurements (±0.11 ft). Ground water flow will have to be inferred using surrounding wells having water table elevation differences greater than 0.22 ft. Figures 4 and 5 show water table maps for May and June. A three point problem is illustrated on these maps to show the inferred direction of ground water flow. Note that the calculated flow direction shifts from due south in May to south-southwest in June.

The ground water gradient shifts with time because the water table is a dynamic surface in a constant state of flux. The rate of change from one point to the other is controlled by ground water recharge and discharge, distance from the recharge and discharge boundaries, and the ability of the aquifer to store and transmit water. Because the Snake River Plain aquifer is heterogeneous its ability to store and transmit water varies with location, so the water level rise and fall within the aquifer in response to changes in recharge and discharge will not always be the same at each well. Therefore, water level measurements should be collected routinely and three point problems worked and water table maps plotted to determine the gradient in the vicinity of the landfills.

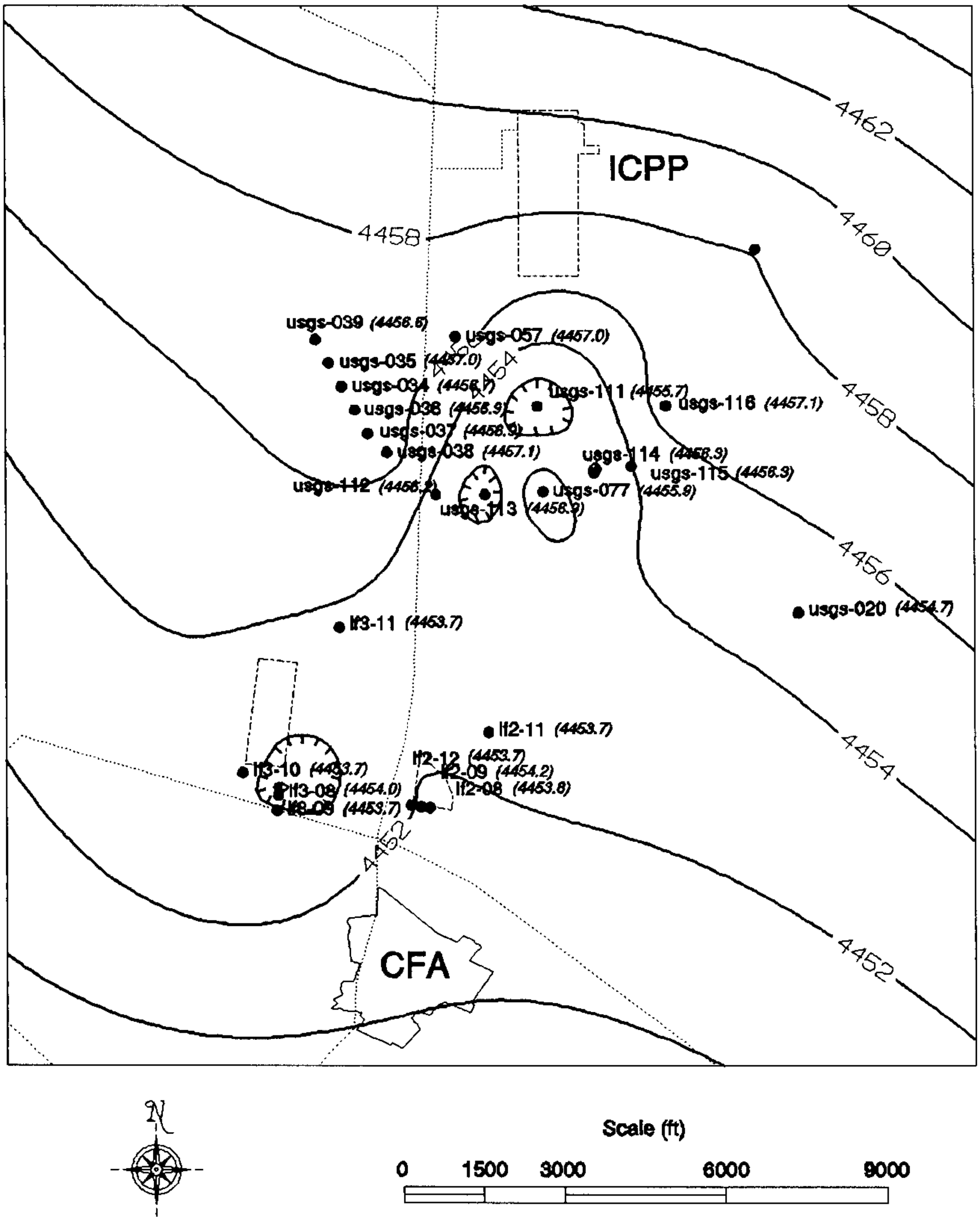

Figure 1. May 1993 water table map without deviation corrections.

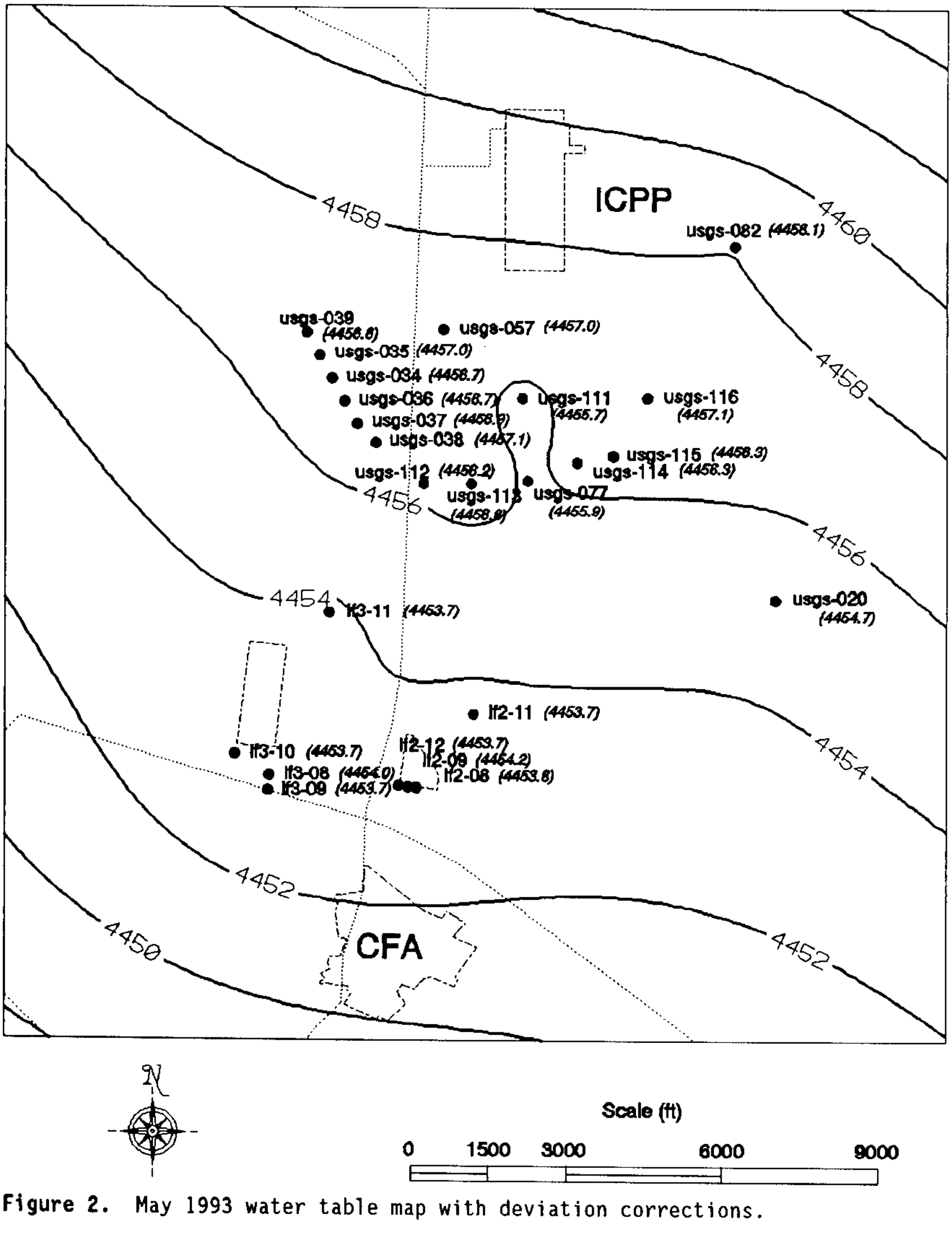

Figure 2. May 1993 water table map with deviation corrections.

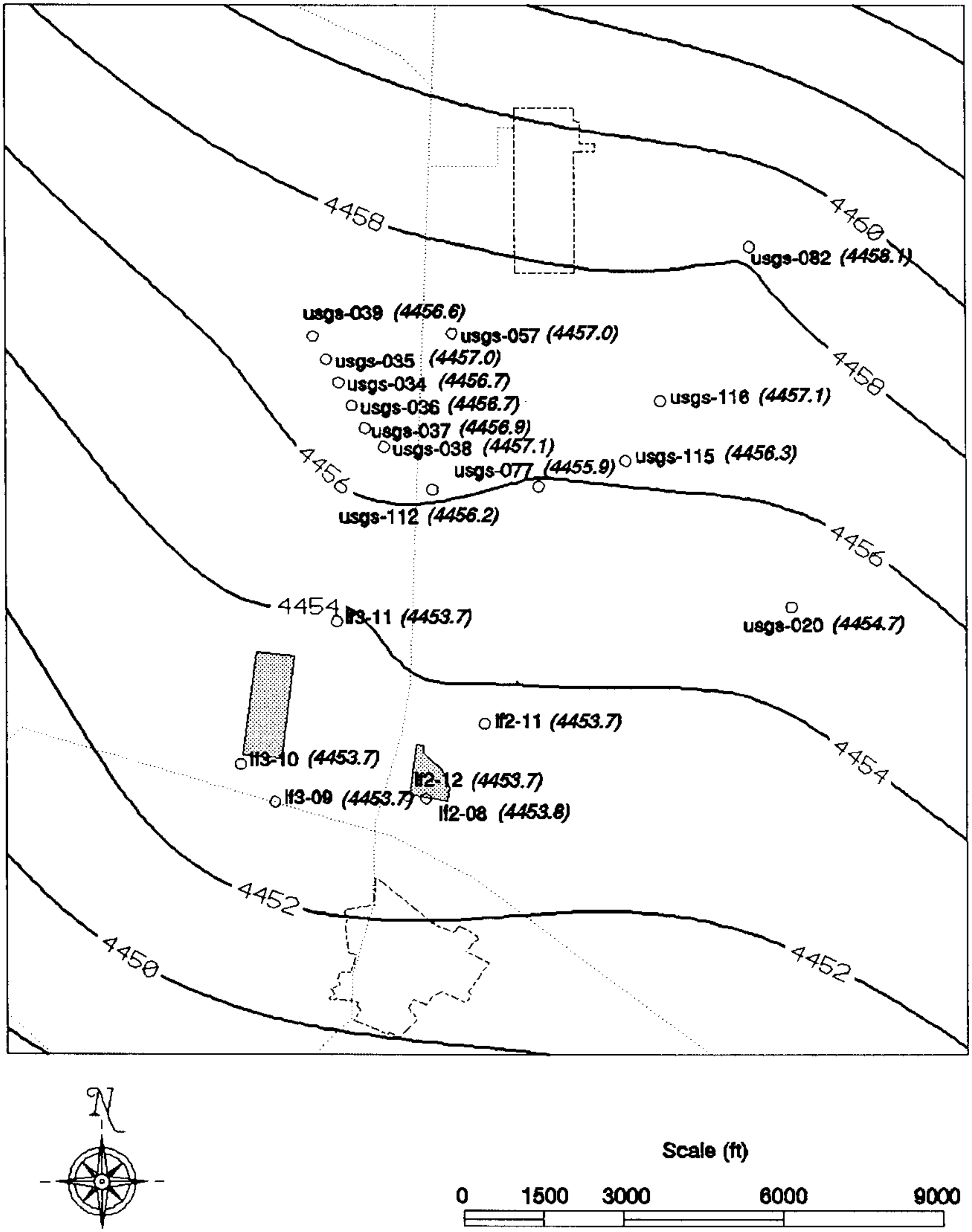

Figure 3. May 1993 water table map using only wells deviating less than 12°.

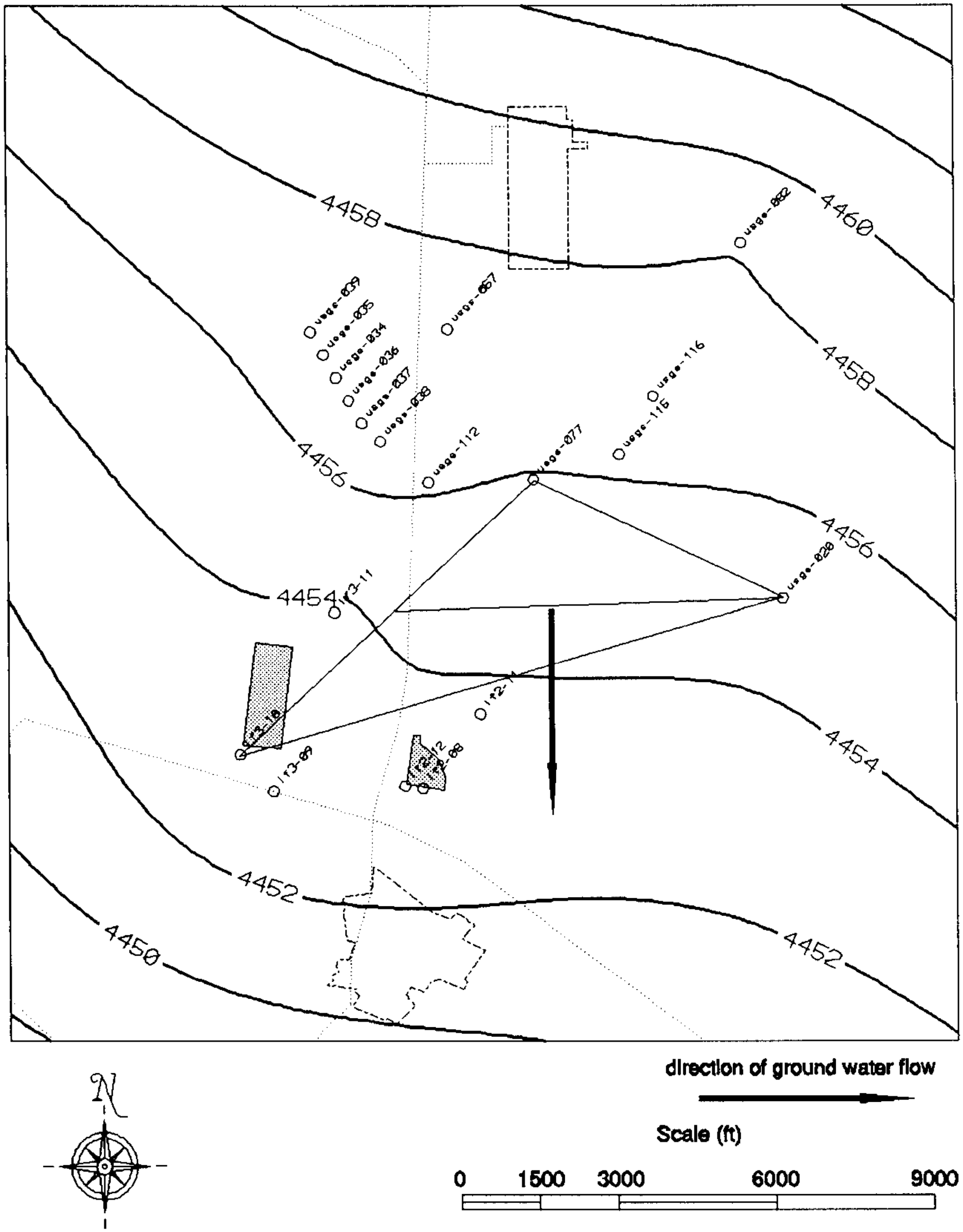

Figure 4. Three point problem showing water table gradient for May 1993.

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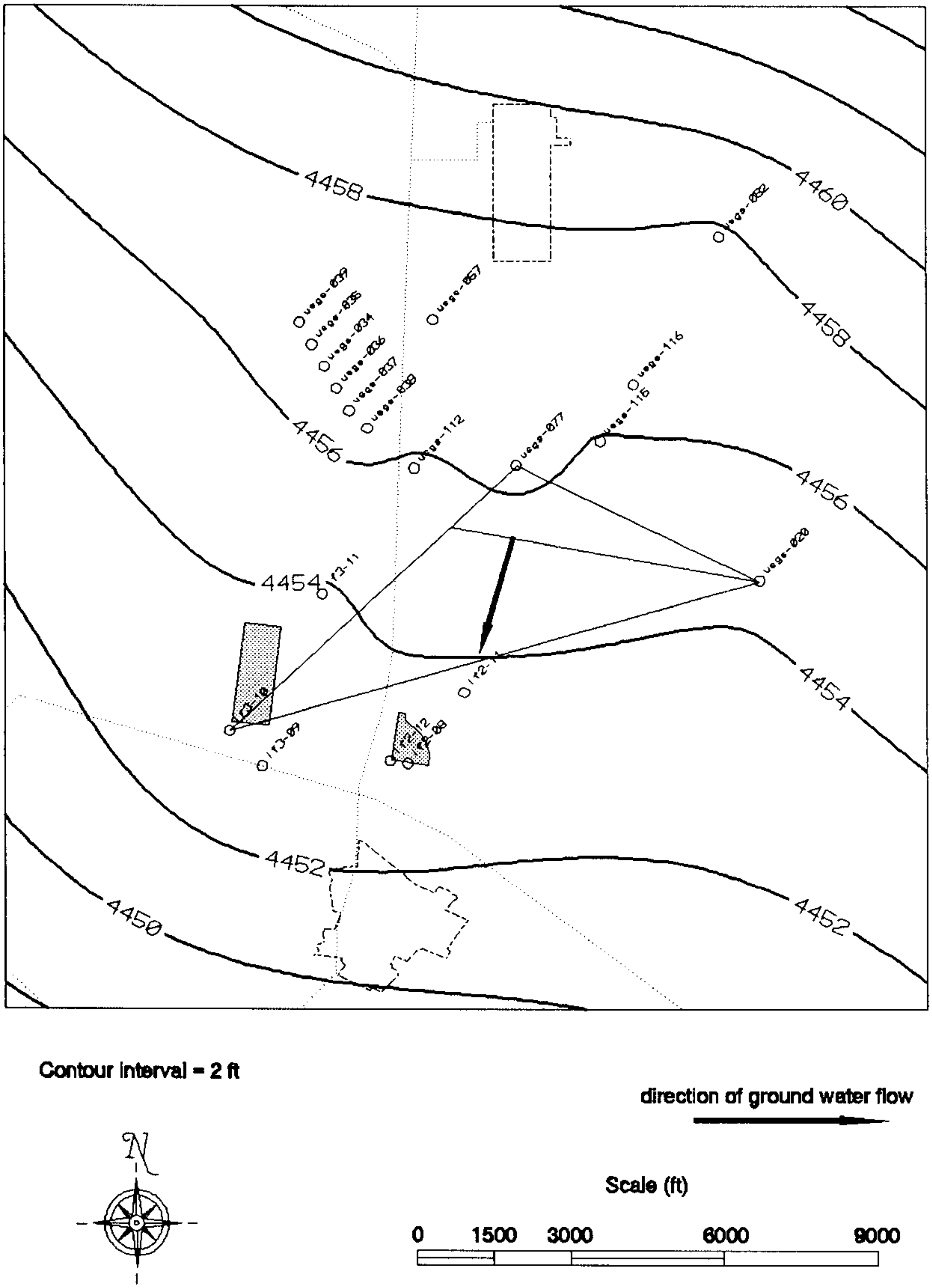

Figure 5. Three point problem showing water table gradient for June 1993.

CONCLUSIONS

A gyroscopic directional survey was conducted on ground water wells in the vicinity of the CFA Landfills II and III to measure borehole deviation from vertical. The survey was conducted by Strata Data Inc. of Casper WY. The purpose of the survey was to determine whether or not anomalies in the water table map of the CFA area could be attributed to borehole deviations, and to determine whether or not the monitoring wells south of the Landfills were indeed downgradient. Borehole deviation corrections eliminate most of the anomalies in the earlier water table maps. However, gyroscopic survey tools have limited accuracy. Because of the high borehole deviations encountered, two different deviation tools were used. Most of the wells were surveyed with the low angle tool, which can measure borehole deviations up to 12°, five wells were surveyed with the high angle tool, capable of measuring borehole deviations up to 35°. The calculated accuracy of the low angle tool is $\pm$0.11 ft, and the calculated accuracy of the high angle tool is $\pm$0.42 ft. When the wells surveyed with the high angle tool are eliminated, the resulting map is consistent with the regional gradient. The calculated gradient direction at the landfills is south to south-southwest for the months of May and June indicating that wells LF3-9, LF3-9, LF3-10, LF2-8, LF2-9, and LF2-12 are on the downgradient side of the landfills.

The water table is a dynamic surface which constantly changes with time. The rate of change from one point to the other is controlled by ground water recharge and discharge, distance from the recharge and discharge boundaries, and the ability of the aquifer to store and transmit water. Because the Snake River Plain aquifer is extremely heterogeneous its ability to store and transmit water varies with location, so the water level rise and fall within the aquifer in response to changes in recharge and discharge will not always be the same at each well. Therefore, water table measurements should continue to be collected and maps plotted and three point problems worked to determine gradient shifts.

REFERENCES

Atwood, D.F., and B. Lamb, 1987, Resolution problems with obtaining accurate ground water elevation measurements in a hydrogeologic site investigation. Proceedings, 1st outdoor action conference. NWWA.

Wylie, A.H., 1993, Gyroscopic directional survey of Central Facilities Area ground water wells. ER-WAG4-31

APPENDIX A

Water level data

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CFA area water levels

well	mp elev	easting	northing	May-93 w/o cor h2o elev	May-93 with cor h2o elev	June-93 with cor h2o elev
lf2-08	4933.10	294356.74	682877.71	4450.8	4453.8	4453.6
lf2-09	4933.85	294194.66	682898.62	4448.3	4454.2	4454.5
lf2-10	4934.23	294266.84	682827.91			4451.2
lf2-11	4930.19	295460.16	684290.72	4453.6	4453.7	4453.7
lf2-12	4934.23	294018.71	682924.45	4453.6	4453.7	4453.6
lf3-08	4941.66	291537.83	683111.08	4449.0	4454.0	4453.8
lf3-09	4942.82	291512.30	682822.69	4453.5	4453.7	4453.6
lf3-10	4944.75	290875.41	683528.93	4453.7	4453.7	4453.7
lf3-11	4936.46	292682.55	686243.56	4453.7	4453.7	4453.8
usgs-020	4919.77	301229.00	686527.00	4454.7	4454.7	4454.3
usgs-034	4933.11	292739.00	690799.00	4456.7	4456.7	4456.5
usgs-035	4934.53	292495.00	691251.00	4456.7	4457.0	4457.0
usgs-036	4933.15	292977.00	690358.00	4456.6	4456.7	4456.5
usgs-037	4933.55	293221.90	689920.10	4456.9	4456.9	4456.7
usgs-038	4934.07	293574.80	689567.00	4457.0	4457.1	4456.8
usgs-039	4934.91	292258.00	691691.00	4456.5	4456.6	4456.5
usgs-057	4927.40	294867.00	691752.00	4456.9	4457.0	4456.6
usgs-067	4919.41	298201.00	691726.00			
usgs-077	4925.99	296490.00	688820.00	4455.9	4455.9	4456.5
usgs-082	4911.77	300453.00	693410.00	4458.0	4458.1	4457.7
usgs-085	4945.31	291427.00	685908.00	4457.5	4457.5	4457.3
usgs-111	4924.80	296386.00	690432.40	4450.2	4455.7	4455.2
usgs-112	4932.05	294488.20	688763.00	4453.4	4456.2	4455.7
usgs-113	4929.62	295405.40	688757.70	4450.5	4456.8	4456.4
usgs-114	4924.43	297437.87	689173.95	4451.5	4456.3	4455.8
usgs-115	4923.22	298128.70	689307.20	4454.0	4456.3	4455.9
usgs-116	4920.94	298782.00	690449.20	4456.9	4457.1	4456.7